SOILING AND CLEANING OF FLOORINGS IN ANIMAL HOUSES

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SUMMARY

Although soiling and wearing of surfaces in animal buildings is a major problem in animal production, only a limited number of investigations of these phenomena have been published. However, the surfaces should be clean and at some sites hygienic e.g. in order to guarantee product quality. Furthermore, there are no common standard procedures used for monitoring hygienic quality of surfaces in animal houses. In the present literature survey, methods for measuring surface properties, wearing and cleanability of surfaces for use in animal houses are introduced and evaluated. In addition, different cleaning and soiling systems are reviewed.

Keywords: soil, detection methods, animal house, piggery, cowhouse

SOILING OF FLOOR SURFACES IN ANIMAL HOUSES

Typical surface materials in animal houses are presented in Table 1. The surfaces in agricultural buildings are subjected to several contaminants, e.g. mixtures of manure, feed and washing waters (Table 2).

Table 1. Typical surface materials used in animal houses

Room	Frequently used surface materials
Walking and laying areas	Concrete, asphalt, rubber mat, stall mattress
Feeding troughs	Special concrete, epoxy, grinded mass
Milking station	Concrete (roughened coatings), ceramic tiles, acrylic concrete, epoxy
Milk room	Concrete, ceramic tiles, acrylic concrete, epoxy
Assistant rooms	Concrete (painted), plastic flooring, acrylic concrete, ceramic tiles

Table 2. Examples of typical contaminants and chemical substances in the floorings in animal houses, mentioned in the literature. The main sources of the harmful substances are manure and feed residues.

Harmful substance	Reference
Acetic acid	DeBelie et al. 1996, ACI 515.1R-79 1985
Butyric acid	Bertron et al. 2005, Nilsson 2005
Capronic acid	Mathiasson et al. 1991
Lactic acid	DeBelie et al. 1996 & 2000
Propionic acid	Bertron et al. 2005
Valerian acid	Mathiasson et al. 1991
Chlorides and sulphides	Calleja Carrete 2005
Aggressive ions NH^{4+}, Mg^{2+}, Cl^{-} and SO_4^{2-}	DeBelie et al. 1996

Manure acidifies over time. Regular and efficient removal of manure when fresh thus helps prevent concrete from becoming brittle (Mathiasson et al., 1991). Similarly to acetic acid, lactic acid also weakens concrete slowly (standard ACI 515.1R, 1985). In a study by De Belie (1997) the feeding method of pigs had the greatest impact on erosion of floorings, the most severe damage being at the liquid feeding site.

MECHANICAL AND STRUCTURAL SOLUTIONS FOR PREVENTING SOILING AND REMOVAL OF SOIL

The floor construction can be solid or slatted. A solid floor is combined with an open or covered drain, whereas a slatted floor requires a collecting system for liquid manure under the floor (De Belie, 2000b). Slatted floors can normally be kept cleaner than the solid floors. A rubber slatted floor caused less soiling and injuries to cows compared to cows on a solid floor in a study by Hultgren and Bergsten (2001). If the inclination (slope) of the floor is 7%, the floor is still comfortable enough for the cows (Nørgaard et al. 2003), but helps the flooring to stay dry and reduces the need for cleaning (McClanahan 2005).

CLEANING METHODS

The manure funnels are normally cleaned mechanically with a scraper, and the feeding troughs with a brush or a rake. Regular pressure cleaning with a pressure of 80–100 bar (Böhm 1998) is the most common cleaning method currently used for floors in animal houses (DeBelie et al. 2000a). Running water from a hosepipe is also a typical means of cleaning animal houses. According to Böhm (1998), the surface should ideally be soaked for 1–2 h before the actual cleaning but this is only rarely the case. In order to make cleaning easier, Larsson (2000) recommended a soaking time as long as 24 h prior to cleaning, but this is rather unrealistic. In the study by Larsson (2000) a washing robot consisting of pressure cleaning and an electronic control system was tested in the cleaning of pig pens. An advantage of using the robot was reduction in manual work, whereas water consumption increased.

Detergents are used only at special sites in cowhouses, such as for cleaning of milking robots and floorings of the milking area. Detergents are also not usually used in cleaning of floorings of piggeries.

DETECTION METHODS FOR CLEANNESS OF SURFACES

In experimental studies, visual and qualitative evaluation methods have mainly been used. An evaluation of different qualitative, semiquantitative and quantitative methods is presented in Table 3.

Table 3. Detection methods of cleanability and evaluation of methods

Detection method	Reference	Evaluation of the method
Visual evaluation	Sundahl 1974, Hörndahl 1995, Puumala&Lehtiniemi 1993	Subjective, qualitative. Requires a large group of evaluators if properly used. Suitable for field and laboratory studies.
Colorimetry	Kymäläinen et al. 2007	Semiquantitative. Detects visible soil on surfaces. Suitable for field and laboratory studies.
Other optical methods (visual and near-infrared optical range)	Zhang et al. 2006	Semiquantitative. The spectral signals can be used for discrimination of dirty and clean conditions of the surfaces.
Chemical and biochemical tests	Larsson 2000	Detects (visible and) invisible organic soil on surfaces. Often sensitive, suitable for clean sites. Suitable for field and laboratory studies.
Microbiological methods	Larsson 2000, Pelletier et al. 2002	Detects (visible and) invisible soil on surfaces. Suitable for field and laboratory studies.
Radiochemistry	Kymäläinen et al. 2007, Määttä et al. 2007	Quantitative. Detects visible and invisible soil both on and absorbed in the surface. Only for laboratory use, requires special equipment.

WEARING OF MATERIALS

Both chemical substances and mechanical impact on floorings cause corrosion and wearing that may promote injuries to the animals. In addition they may make cleaning difficult, thus promoting spreading of diseases (DeBelie 1997, DeBelie et al. 2000). In practice, animals and high pressure cleaning both cause mechanical wear in the flooring (Mathiasson et al. 1991, O'Donnell et al. 1993, ACI 515-1R-79 1993, DeBelie et al. 1996, DeBelie 1997, DeBelie et al. 2000a&b, Calleja Carrete 2005), which may increase both its roughness and the space between the slats. However, in studies by Barnes (1979) and De Belie (1997), high pressure cleaning did not intensify the erosion of concrete flooring. According to Barnes (1979), a pressure of 7 N/mm (7 MPa) may wear the surface of low-quality concrete. According to De Belie (1997), detergents may theoretically have a role in wearing of the floorings: in her study detergents rather postponed than caused erosion of the flooring. This may be a consequence of improved cleaning leading to decreasing chemical attack on the flooring. Great amounts of water may also dilute chemicals, thus decreasing the damaging of the flooring.

In addition to coatings, the chemical resistance of concrete can be affected by its composition and porosity (Shaw 1988, Puumala&Lehtiniemi 1993, Pelletier et al. 2002, Calleja Carrete 2005). The manufacturing technique of concrete, e.g. after-treatment, affects significantly the chemical and mechanical resistance of the flooring (Shaw 1988).

CHRACTERIZATION OF MATERIALS

Several techniques have been developed over the years to quantify the topography of surfaces. These can broadly be divided into two categories: contact (profilometry) and non-contact methods. In recent decades, a variety of new methods have been developed for the evaluation of surface topography properties, including different microscopic methods e.g. atomic force microscopy, phase shifting interferometry, stereo scanning electron microscopy and laser confocal scanning microscopy. Different techniques used to study surface topography are presented in Table 4.

Table 4. Surface topography – a summary of the measurement techniques used for polymeric and ceramic materials (modified from Kuisma 2006, in which the original references are presented)

Device	**Resolution**		**Measurable area**	**Evaluation of the method**	**Examples of typical (or possible) materials**
	Lateral	**Vertical**			
Stylus profilometry	100 nm	0.5 nm	Typically a few millimetres	No sample preparation. Stylus can damage the sample. Slow measurement speed in 3D. Not suitable for concrete, similar porous materials or dirty surfaces.	(Plastics)
Optical profiler	350 nm to 9000 nm	0.1 nm	0.2 nm to 10^5 nm	No sample preparation, non-contacting. Reflective light. Suitable for various surface materials.	Ceramics, polymeric materials
Scanning electron microscopy (SEM)	1 nm to 50 nm (in secondary electron mode)	10 nm to 20 nm	Less than 0.1 mm, up to 10 cm	High magnification imaging. Samples must be vacuum compatible. Requires a conducting surface. Suitable for various surface materials.	Polymeric materials
Atomic force microscopy (AFM)	0.2 nm to 1 nm	<0.03 nm to 0.05 nm	10^3 nm to 10^5 nm	High resolution pictures. Scans small areas, which makes this method unfavourable for the relatively rough surfaces used in animal buildings.	Polymeric materials
Scanning tunnelling microscopy (STM)	0.2 nm	<0.03 nm to 0.05 nm	10^5 nm	High resolution pictures. Requires a conducting surface. Scans small areas, which makes this method unfavourable for the relatively rough surfaces used in animal buildings.	Polymeric materials
Confocal microscopy (COM)	500 nm to 4000 nm	2 nm to 2000 nm	100 nm to $6x10^5$ nm	Minimal sample preparation. Background texture often confuses the detectors. Suitable for various surface materials.	Polymeric materials, ceramics

Profilometric analysis is a routine technique used in material science to quantify the morphology of material surfaces or the irregularities of fracture boundaries. Since stylus – material interactions may dramatically affect measurements especially when porous and brittle materials are examined, non-contact techniques offer a better alternative for studies of concrete and similar materials. Scanning electron microscopy (SEM) allows a qualitative approach to surface topography and is widely used in industrial and biological studies. SEM is a popular technique used in the investigation of structures of surfaces and wear particles. However, interpretation of the images is not necessarily straightforward and does not readily yield quantitative data about the height of surface features.

Atomic force microscopy (AFM) is also known as scanning force microscopy (SFM). The atomic force microscope is a combination of the principles of the scanning tunneling microscope (STM) and stylus profilometer. The atomic force microscope is a versatile tool for measuring surface topography. Because of its wide range of applicability, AFM has become an increasingly important tool for the measurement of surface roughness on the nanometer scale. Additionally, AFM methods are able to measure surfaces in a number of modes: contact, intermittent-contact and non-contact.

Confocal profilers and confocal microscopes have been developed to measure the surface height of smooth to very rough surfaces.

CONCLUSION

The surfaces in agricultural buildings are subjected to several contaminants. Water and mechanical means (e.g. scrapers and water pressure) are mostly used for cleaning animal houses. The cleanability of floorings and other surfaces in animal buildings can be enhanced with structural solutions (e.g. by using slatted floors) and with coatings or modifications of concrete and other materials. Several methods are available for examining and monitoring cleanliness of surfaces and for their characterization. Methods from other areas of materials sciences have been adopted for use. For cleanability studies, suitable optical, chemical, biochemical and microbiological methods are available for field use. For laboratory studies, the radiochemical measurements offer a potential quantitative alternative. For surface topography studies of relatively rough surfaces such as concrete, scanning electron microscopy, optical profilometer and confocal microscope are among the suitable options. Their area examined is large enough and the porosity (local holes and elevations) does not prevent use of the devices. The principles, operation ranges (e.g. the amount of soil) and suitability for laboratory or field use vary considerably between the methods. Selection of suitable methods is thus needed for laboratory studies and for field use.

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